Hope, at the foot of the Beardmore, Glacier, in 83° 30′ S. These field parties in 160 days traveled 1,561 miles, of which distance 830 miles were made in laying down from Hunt Point the depot at Mt. Hope. Scurvy attacked the main party in the field and one man, Spencer Smith, died the day before their return journey was completed. Later Captain Mackintosh and Hayward perished in a blizzard during a short journey—probably from disruption of the ice-pack. Shackleton went at once to the rescue of this party, sailing in the *Aurora,* which was commanded by the veteran polar captain, Davis, in December, 1916. The voyage was short and the marooned men were brought safely to Hobart.

The illustrations are of unusual value, conveying as they do a clearer and more accurate view of polar scenes and lands, and especially as to Caird Coast and Elephant Island. The set illustrating various types of ice are important, and should become standard.

The narrative is marked by its appreciation of the members of the two expeditions, and from it one is confirmed in the realization that Shackleton is a leader of men of unusual ability and force. Considerate of his subordinates, he never spared himself, and under a less able leader the Weddell Sea party would have perished.

A. W. GREELY

SPECIAL ARTICLES

THE ASH OF DUNE PLANTS

SAND, the final residue after weather and water have worked their will on the silicate rocks, is possibly the poorest substratum in a chemical sense for the growth of plants. Under the action of glaciers and running water followed or accompanied by the hydrolyzing action of water in the presence of carbon dioxide and lastly subjected to the monotonous attrition of particle against particle acutated by wave motion, nothing is left of the original rock masses except partially rounded particles of quartz accompanied by grains of the more resistant silicate minerals and magnetic oxide of iron (Fe_3O_4). The finely divided silt and clay produced during the formation of the sand by wave abrasion and containing the most valuable mineral constituents for plant growth, consisting as they do of particles approaching colloidal dimensions, remain easily in suspension and are carried away by very slight water currents to be deposited far apart from the sand in quiet places. That which remains with the sand after deposition on beach or shore is carried away by the wind and redeposited at a distance, so that beach, shore or dune sand contains a minimal quantity of clay—not enough in a handful to cloud a tumbler of water.

In ordinary sand the silica content varies from approximately 92 to 98 per cent. A part of this exists free as quartz and a part in combination in silicate minerals which have resisted decomposition. The following analyses from Clarke[1] show the composition of sands from various sources.

	A	*B*	*C*	*D*	*E*	*F*
SiO_2	77.78	90.74	82.13	89.99	55.03	91.39
Al_2O_3.......	9.95	5.16	9.04	7.36	14.12	5.44
Fe_2O_3	2.55	1.14	2.94	.72	10.15	.89
FeO.	.21	.08	......	.13	.....	..16
MnO	.....	Trace	......	Trace	.....	Trace
CaO	.71	.69	1.28	.46	6.88	Trace
MgO.......	.17	Trace	.84	Trace	6.38	Trace
K_2O	2.50	1.19	1.93	.33	1.66	1.19
Na_2O	1.82	.26	.95	.33	.87	.70
P_2O_5.......	.....	......	.20	......	.....	......
Ignition	2.74	1.30	1.01	.60	4.55	.65
	98.43	100.56	100.01	100.43	99.64	100.42

A, B. Glacial sands.
C. Average of five river sands.
D. Sea sand.
E. Sea sand derived from subsilicic igneous rocks.
F. Blown sand.

In spite of its chemical poverty and its inadequacy as a soil for the support of nearly all agricultural plants, sand, nevertheless, has certain physical advantages which are of importance and valuable to such vegetation as

[1] "The Data of Geochemistry," by F. W. Clarke, Bull. 616, U. S. Geological Survey.

can maintain life on low mineral rations; (1) on account of its porosity it is always well drained; (2) it is likewise well aerated; (3) it allows free lateral and vertical movement of ground water; (4) on account of its low capillary absorption of water it has a very low wilting limit;[2] in other words, it

	Water per 100 of Dry Soil When Plants Wilt	Hygroscopic Water
Coarse sand	1.5	1.15
Sandy garden soil	4.6	3.00
Fine sand, with humus.	6.2	3.98
Sandy loam	7.8	5.74
Chalky loam	9.8	5.20
Peat	49.7	42.30

gives up its water readily to plants and even though it contains little, that little is available for the growth of vegetation; (5) it offers little obstruction to the growth and extension of roots, when compared with stiffer soils such as clay loams and clay.

Probably its greatest physical disadvantage is its tendency to drift with the wind with the resultant root-uncovering or top-burying action. However, this is not a serious menace to typical dune vegetation for the great root systems of most dune plants permit uncovering in some degree while even a continuous "hilling-up" of most of them during their growth appears to work no harm.

The dune region of Northern Indiana along the south shore of Lake Michigan, with which the writer is most familiar, has been the subject of numerous botanical as well as general investigations, and has attracted much interest recently since the proposal has been made to establish a National Park there. Cowles in a series of interesting papers[3] has discussed the plant ecology of the region and Shelford[4] the animal ecology.

[2] A. D. Hall, "The Soil," p .85.

[3] "Ecological Relations of the Vegetation of the Sand Dunes of Lake Michigan," *Bot. Gaz.*, 27, pp. 95, 167, 281, 361 (1899). Also "Plant Societies of Chicago and Vicinity," Bull. 2. Geog. Soc. of Chicago.

[4] "Animal Communities in Temperate America," Bull. No. 5. Geog. Soc. of Chicago.

The variety of plants in the district between Gary and Michigan City and extending about 1 or 1½ miles back from the lake shore is very great. The storm beach, to the upper limit of storm waves and driftwood (the region of the "singing sands") practically devoid of vegetation, is usually about 40 to 100 feet wide, but naturally varies with the season and wind intensity. There may be a few quick growing annuals such as sea kale (*Cakile americana*), bugseed (*Corispermum hyssopifolium*), etc., in this belt, especially during a few weeks of summer calm. Between the storm beach and the fixed dunes lies the belt of young dunes in the making, and here grow both annuals and perennials. The sand cherry (*Prunus pumila*) is here, perhaps of all the most characteristic shrub, but along the same stretch grow red osier dogwood (*Cornus stolonifera*), cotton woods (*Populus deltoides*), low willows (*Salix glaucophylla, Salix adenophylla*), artemesia (*Artemesia caudata*), Pitcher's thistle (*Cirsium Pitcheri*), the grasses, *Calamovilfa longifolia* (abundant) and *Ammophila arenaria* (less abundant. *Andropogon scoparius* (*littoralis*) does not grow as a rule near the storm beach but higher up on the fixed or partially fixed dunes.

Back of the storm beach and the embryonic dunes rise the permanent or wooded dunes, well fixed by vegetation, except where blowouts have cut through and started the sands to drifting once more. In some places the fixed dunes rise abruptly from the rather narrow storm beach, and in others low, moving or semi-fixed dunes run back from the shore for long distances. But the first example is typical.

Usually in the region discussed the shore consists of the fine sand described with relatively little shingle, but after a succession of severe storms as during the past two years, the amount of shingle increases until the shore is covered with it for a width of ten to forty feet. Undoubtedly this assists in holding the sand and preventing its drifting.

The sand of the northern Indiana dune region is considerably finer than that of some

others, for example Cape Cod, and in fact the entire Atlantic coast, drifts easier with the wind and is less stable unless indeed it is stabilized by growing vegetation. A rough sieve analysis gives the following proximate physical composition, the percentages shown being the amounts passing or retained on sieves of the indicated mesh.

PHYSICAL ANALYSIS LAKE MICHIGAN SAND

	Shore Sand	Dune Sand
Finer than 100 mesh	3.3	3.4
Finer than 80 mesh	9.4	11.3
Finer than 60 mesh	49.2	46.3
Coarser than 60 mesh	50.8	53.7

When examined chemically the sand shows no remarkable peculiarity with the possible exception of a rather high percentage of calcium which may be accounted for by the fact that the native rock of the region is limestone and the gravel of the boulder clay of the west shore of the lake is composed largely of the same rock. Analyses of the shore sand and of the dune sand give results which are practically identical. The following analyses were made in 1911.[5]

CHEMICAL ANALYSIS OF SHORES AND DUNE SAND

	Shore Sand	Dune Sand
Loss on ignition	1.00	0.90
Silica	92.00	91.90
Iron and Al. oxides	3.24	4.30
Calcium oxide	1.36	1.36
Magnesium oxide	0.56	0.72
Sodium oxide	0.47	0.63
Potassium oxide	0.85	1.00

Another analysis of sand from a blowout was made in 1918 and gave the following results:

ANALYSIS OF SAND FROM BLOWOUT

Silica (SiO_2)	90.28
Iron oxide (Fe_2O_3)	1.03
Aluminum oxide (Al_2O_3)	3.55
Calcium oxide (CaO)	1.57
Magnesium oxide (MgO)	0.73
Sodium oxide (Na_2O)	2.22
Potassium oxide (K_2O)	1.05
Phosphoric anhydride (P_2O_5) trace, less than	0.01%

[5] Analyses by L. S. Paddock.

Approximately 90 to 92 per cent. of the sand is silica but it should be remembered that the remaining 8 to 10 per cent. consisting of calcium, magnesium, iron, aluminium, sodium, potassium, etc., is contained in undecomposed silicate minerals. Under the hand lens, while the clear white, yellow or red sand quartz grains greatly predominate, there is present also, in characteristic fashion, a considerable proportion of bright-colored and dark particles, red, brown, green and black feldspar, mica, hornblende, magnetite, etc., making up, let us say, approximately 25 per cent. of the total. From these particles the dune plants must in the main derive their supply of soluble inorganic substances necessary for nutrition. It should be noted that these rock particles are practically in their unaltered condition, any decomposed or finely disintegrated portions having been mostly dissolved or washed away by the waves or blown away by the wind. However, when the sand is agitated with water there is always present a very small quantity of colloidal particles or clay which is undoubtedly important for the growth of plants. The amount, however, is so slight that it scarcely fails to leave the water clear and could be entirely disregarded for the purpose of the argument.

The integration of chemical infinitesimals by the living organism is not an isolated or unique phenomenon, particularly in the vegetable world. It is nevertheless a matter of the greatest interest, whether it consists in the elaboration of complex carbon compounds from the carbon dioxide of the atmosphere, wherein this substance occurs at a dilution of about 3 parts in 10,000, or the concentration of potassium salts by the giant kelps of the Pacific (*Macrocystis, Pelagophycus, Nereocystis,* etc.) from sea water which contains about 4 parts potassium per 10,000 or only about 1/30 the amount of sodium present; but in the two instances cited, the raw material is brought to the plant in suitable quantity and form of combination, if in a condition of great dilution, from the enormous

reservoirs of air and ocean. In the case of dune plants the root systems must go after their mineral food supply and search the sand grains for it. Not only this, they must convert the needed portions of insoluble silicates into soluble compounds suitable for absorption and metabolism. This they are well equipped to do; for whatever other characteristics various species of dune plants may have and howsoever greatly they differ from one another, they are alike in possessing extraordinary root systems. This does not mean that all the root sytems belong to one type or class but that all are of relatively large dimensions and well adapted to exploring for their food supply or failing this to storing up a supply by slow accumulations through the year for a brief season of active growth or short blooming period—for example, the bird-foot violet (*Viola pedata*). The distances which some of the longer roots travel, horizontally, parallel with the surface, or in a downward direction, are astonishing and all but unbelievable unless one has traced such roots by pulling them out; distances to be measured in units of yards or rods rather than feet or inches. Even quick-growing annuals like sea kale (*Cakile americana*) will send out horizontal root branches in length many times the height of the plant—a plant ten inches high may have horizontal root branches ten feet long.

For the determination of ash constituents, seven typical species were selected. The sand cherry (*Prunus pumila*), artemesia (*Artemesia caudata*), black oak (*Quercus coccinea tinctoria*), the three grasses, *Calamovilfa, Ammophila* and *Andropogon,* and the scouring rush (*Equisetum hyemale* var. *intermedium*).

The sand cherry sample consisted of stems and a few leaves, the artemesia of stems, leaves and seeds, the oak of a section of trunk, the grasses of stems, leaves and seeds, and the scouring rush of stems. These were first carefully burned on clean iron pans to a blackish or gray ash, then taken to the laboratory and the ashing completed at a moderate red heat in muffles. The analyses follow:[6]

ANALYSIS OF ASH FROM ARTEMESIA AND PRUNUS

	Artemisia	Prunus
Silica	12.12	1.50
Iron oxide (Fe_2O_3)	1.74	0.71
Aluminum oxide (Al_2O_3)	0.42	0.02
Calcium oxide (CaO)	35.47	44.13
Magnesium oxide (MgO)	6.41	4.25
Phosphoric anhydride (P_2O_5)	3.95	3.25
Carbon dioxide (CO_2)	21.40	35.48
Mangano-manganic oxide (Mn_3O_4)	0.12	0.06
Chlorine present as chlorides	1.75	0.26
Sulphuric anhydride (SO_3)	6.00	0.79
Sodium oxide (Na_2O)	0.52	0.40
Potassium oxide (K_2O)	11.61	10.94

ANALYSIS OF ASH FROM QUERCUS AND COMMERCIAL SAWDUST

	Quercus	Sawdust
Silica	32.38	12.84
Iron oxide	1.50	2.55
Aluminum oxide	0.70	3.05
Mangano manganic oxide (Mn_3O_4)	0.24	0.72
Phosphoric anhydride	0.91	1.40
Sulphuric anhydride	3.33	2.09
Carbon dioxide	18.04	22.40
Chlorine present as chlorides	trace	trace
Calcium oxide	28.86	36.00
Magnesium oxide	3.42	4.13
Potassium oxide	9.51	13.39
Sodium oxide	0.82	1.26

ANALYSIS OF ASH FROM FOUR DUNE PLANTS

	Equisetum	*Calamovilfa* Ash	*Andropogon* Ash	*Ammophila* Ash
Silica	49.44	58.74	65.40	48.56
Iron oxide	1.04	1.61	2.52	2.85
Aluminum oxide	2.26	1.69	2.57	3.02
Calcium oxide	13.36	11.61	10.19	19.00
Magnesium oxide	3.67	3.72	3.21	4.29
Potassium oxide	6.01	10.70	6.68	6.32
Sodium oxide	10.37	4.52	4.00	8.18
*Chlorine	3.83	1.83	2.57	1.10
Sulphuric anhydride	8.97	4.58	1.55	4.95
Phosphoric anhydride	2.55	2.04	2.04	2.05
*Oxygen equivalent	0.86	0.40	0.55	0.25

For comparison with the black oak ash, an analysis was made of the ash on a sample of ordinary commercial oak sawdust, source and

[6] I am indebted to Messrs. L. S. Paddock and W. B. Cochrane for the analytical work on the ash of the various dune plants.

soil unknown This sawdust would represent a mixture of samples from numerous trees and possibly represent several species grown on ordinary forest soils.

From these analyses several interesting conclusions are to be drawn. The dune plants have obtained and concentrated in their tissues, the same mineral constituents commonly found in plants growing on good soils, and these have been accumulated in approximately the same relative proportions. It is natural to suppose that the concentrations of the various substances in the soil would have some influence on the composition of the ash. If a soil contain a relatively large amount of potassium or phosphorus, or calcium or silicon, one might expect that these elements would be contained in the plant ash in relatively large proportion. While this influence of total quantity present in the soil is of some effect, it is not determinative. The plant takes what it needs. Contrast *Prunus* with *Artemisia, Quercus* or the three grasses or the scouring rush and note the astonishingly low silica content of *Prunus* ash compared to any of the others and the relatively high calcium. It is astonishing indeed to find a negligible quantity of silica and an extremely large proportion of calcium in the ash of a plant grown on such a highly silicious soil.

Consider those elements derived from the soil which are assumed to function in the essential metabolism of the plant, iron, manganese, calcium, magnesium, potassium, phosphorus, sulphur. From most inadequate and insufficient sources the dune plants have obtained their requirements of these necessary elements. On such a soil as beach sand, the ordinary plants of agriculture would wilt and starve. It would probably not be possible to successfully grow any sort of plant which in addition to maintaining itself normally, stores up abundantly large quantities of organic compounds suitable for human food in roots, leaves, fruits or grains. Plants of this sort would probably not reach maturity or grow at all. Certainly they would not develop into a food-producing crop, but the characteristic dune plants are at least sufficient unto themselves, carry through their life cycle successfully and win from a most refractory soil their necessary mineral sustenance. Prunus refuses silicon and gathers in large supplies of calcium whereas the grasses and the scouring rush store up large quantities of the former and are satisfied with one fourth to one third as much calcium as Prunus requires.

Those other elements, aluminium, silicon, sodium and chlorine, consistently present in plants, but apparently not essential to growth (as determined by pot and water cultures) are yet present in the ash of dune plants, although, with the exception of silica, in small proportion. Must we conclude that these elements although not essential to growth, are nevertheless not harmful, and that they are absorbed by a selective apparatus which while highly efficient is not absolute in its action, since the physiological requirements of the plant are satisfied short of positive rejection of harmless non-essentials? Or, on the other hand, are some or all of these elements, while not necessary for the normal metabolism of the plant, at least desirable in some unknown way in connection with osmotic pressures?

The older chemists puzzled much over the meaning of plant ash composition and not without reason. However regrettable the fact is, we are forced to admit that to-day we know little more in regard to the fundamental requirements of plants as regards mineral substances and the ability to obtain them from various soils and under various conditions than they did. In Liebig[7] are some hundreds of analyses in the old chemical notation unclassified save as to species and with the components in every conceivable proportion. The names of the analysts are appended but this throws little light on the subject as some of them are known to fame, others all but lost in oblivion, and as the methods of analysis used by the various investigators are not given, the degree of accuracy attained in the various cases remains unknown. Undoubtedly the

[7] "Die Chemie in ihrer Anwendung auf Agricultur und Physiologie."

methods used were less perfect than those in use to-day but even assuming that the analyses are reasonably accurate, the varying proportions and the various ingredients in the case of different species and different analyses are such that it is impossible to discern any rule or law governing their absorption by the plant. It is evident that certain mineral constituents are necessary for the plant's growth, but the minimum amount required of individual elements or the relative amounts of various elements apparently depend on a number of variables, such as species and race of plant, the soil, the season, the rainfall, the state of cultivation, etc., to such an extent that it is doubtful whether or not any sort of rule governing these proportions can ever be formulated. About all we can say is that certain elements are necessary for the normal growth of the plant and either the plant obtains these at the proper time or it suffers injury or death.

Small wonder that the older chemists failed to find the rule and all credit to them that they did ascertain the main fact.

Considering plants of all sorts, and all parts of plants, silicon is the greatest variable of all. It is invariably present but only in small amount, even to a fraction of one per cent. in fruits and edible grass seeds (grain), whereas in the stalks of the same plants it may constitute as much as seventy-five per cent. of the ash. In the light of these facts, it has been looked upon by some authors as a material of construction (the first and most natural thought) rather than as a physiologically functioning substance. This view receives some confirmation from those obvious cases in which silica serves as a structural support, as in the scouring rush and diatoms. There can be no doubt that plants acquired the silica habit early in their evolutionary history and it yet may be found to function physiologically, osmotically or structurally. It is difficult to think of an active, surviving, plant organism absorbing and storing up such a substance or any substance which has and can have no real and positive use in its life cycle. Unless silicon functions in some way in plant metabolism or serves as a building material, it is most difficult to explain the high relative portion of this element in the grasses and scouring rush, the moderate amounts in Artemesia and the almost negligible quantity present in Prunus.

It is interesting to visualize the activities of the growing root tip as it projects itself among the sand grains, moving under the reactions of the various tropisms in such wise that the weal of the growing plant is conserved; turning as necessity arises first in one direction, then in the other, but on the whole maintaining its direction, since there are no serious obstructions in the dune soil; wedging its way molelike underground, expanding, holding fast; neglecting grains of silica, lying close to potash silicates, absorbing chance molecules of calcium bicarbonate and phosphates, furnishing the chemical means if need be, of bringing the insoluble substance it requires into solution; keeping the cell pumps going to furnish the water supply to the plant in time of rain or drought; a very center of ceaseless, slow, sure activity, in which all the forces of nature seem to be at work to maintain a useless bitter plant.

W. D. RICHARDSON

CHICAGO, ILL.

THE UTAH ACADEMY OF SCIENCES

THE thirteenth annual convention of the Utah Academy of Sciences was held in the physics lecture room of the University of Utah at Salt Lake City on April 2 and 3, 1920.

At the business meeting at the close of the session, April 3, the following members were elected to fellowship in the Academy: O. W. Israelson, Utah Agricultural College, Logan; T. B. Brighton, University of Utah, Salt Lake City, and R. A. Hart, Springville.

The following were elected to membership: Dr. E. L. Quinn, University of Utah; Dr. E. E. Erricksen, University of Utah; Orin A. Ogilvie, University of Utah; Wm. Z. Terry, Ogden; Geo. P. Unseld, Salt Lake City, and Albert S. Hutchins, Springville.

The constitution was amended raising the annual dues to two dollars, effective for the present year.